Fermi National Accelerator Laboratory

Project X

MEBT Buncher Cavities.

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Project X Collaboration Meeting at LBNL

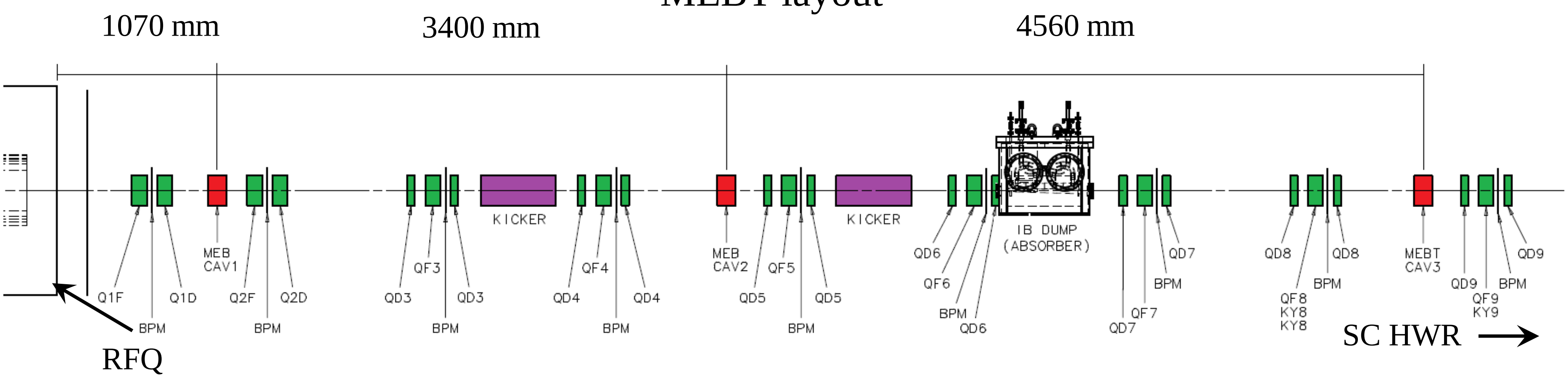
Talk Outline

Project X

- **QWR re-buncher RF design**
  - Main parameters of the re-buncher
  - Steering effect
  - Multipacting
  - Power losses
  - Power coupler
  - Tuners
- **Current mechanical design**
  - Cooling scheme and thermo-stress analyses
- **Conclusion**

General

MEBT layout

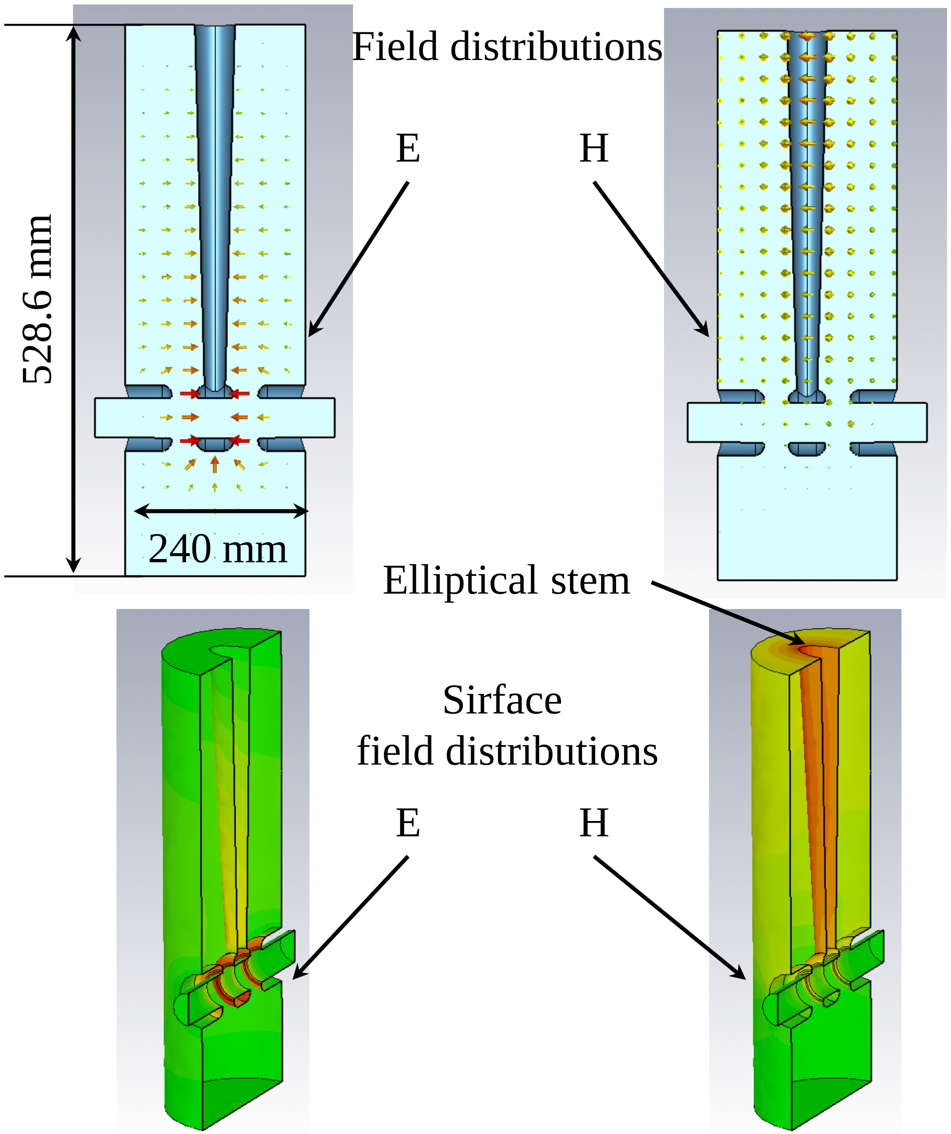


Coupler functional requirements	
Coupler Power Rating (full reflection), kW	4
Coupling coefficient	1.0
Coupler feeder – standard coaxial with impedance	50 Ω
Number of vacuum windows	1
Diagnostic ports, e-probes	1

Cavity functional requirements	
Number of Bunching cavities	3
Frequency, MHz	162.5
β	0.067
Operating temperature, C	35
Operating mode	CW
Operating Accelerating Voltage at β=0.067, kV	70
Maximum voltage, kV	100
Bare cavity Q	10000
R/Q, Ω	500
Coupler coupling type, electric(E) or magnetic(M)	M
Power loss at maximum voltage, kW	≤2.2
Frequency tuning range, kHz	100
Minimum beam aperture, mm	**≥30**
Overall module length; flange-to-flange, m	**≤0.35**

We compared pillbox (350 MHz and 162.5 MHz) and QWR (162.5 MHz) cavities. QWR cavity has been chosen.

Current QWR RF design



Parameter	Value
Frequency, MHz	162.5
Q factor	10530
Aperture radius, mm	20
Gap, mm	2x23
Particle energy, MeV	2.1
Effect. shunt impedance, Ohm	5.3e6
R_eff/Q	503
Effective voltage, kV	70
Power loss in copper, kW	0.92
Max. elec. surface field, MV/m	4.2

Remarks on optimization

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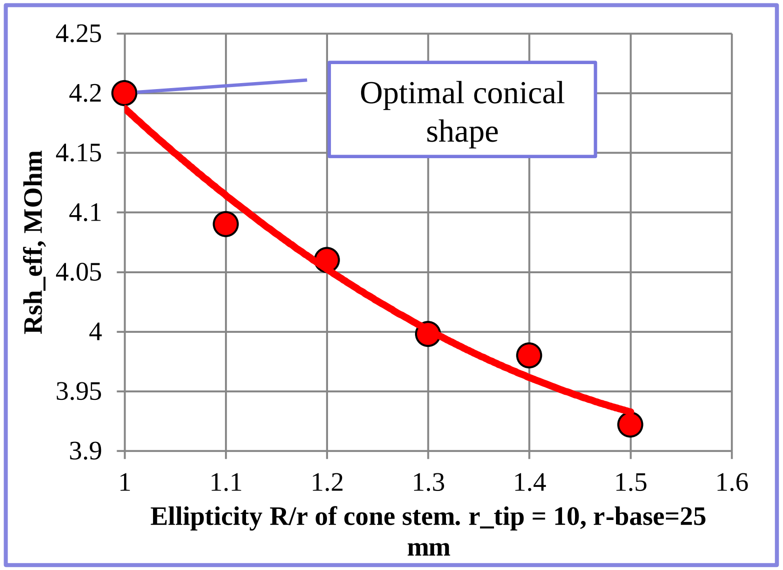
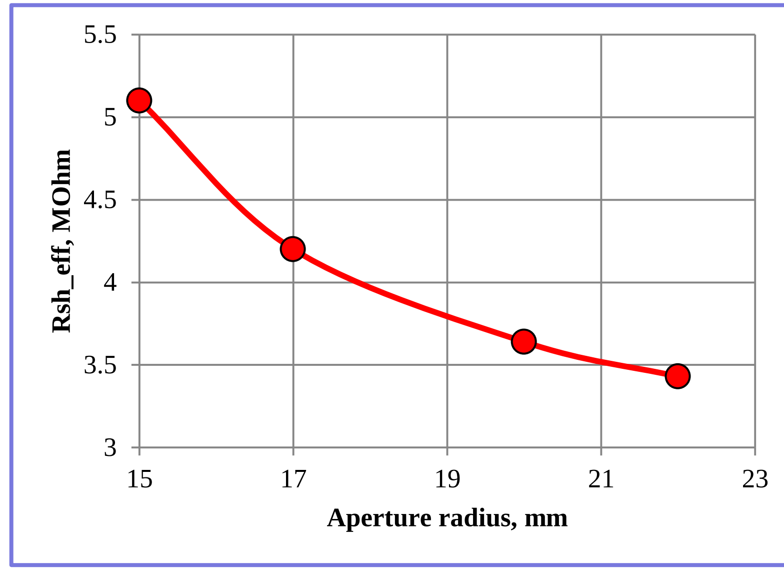
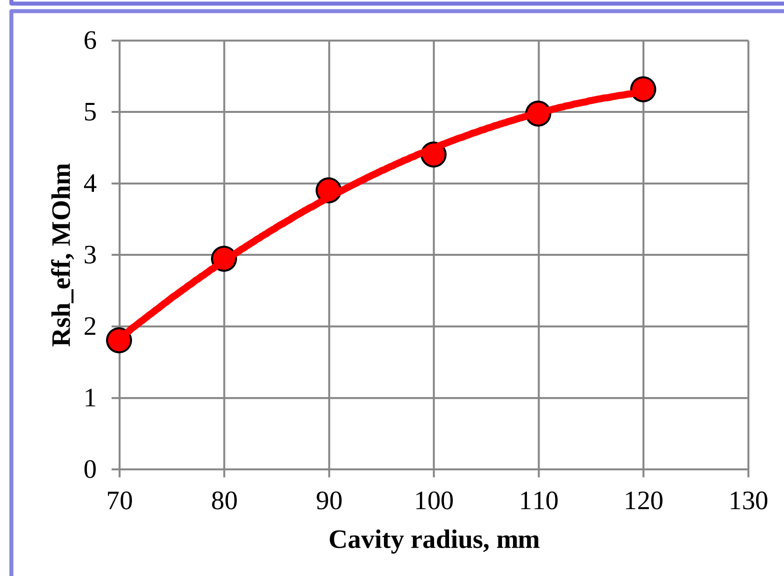




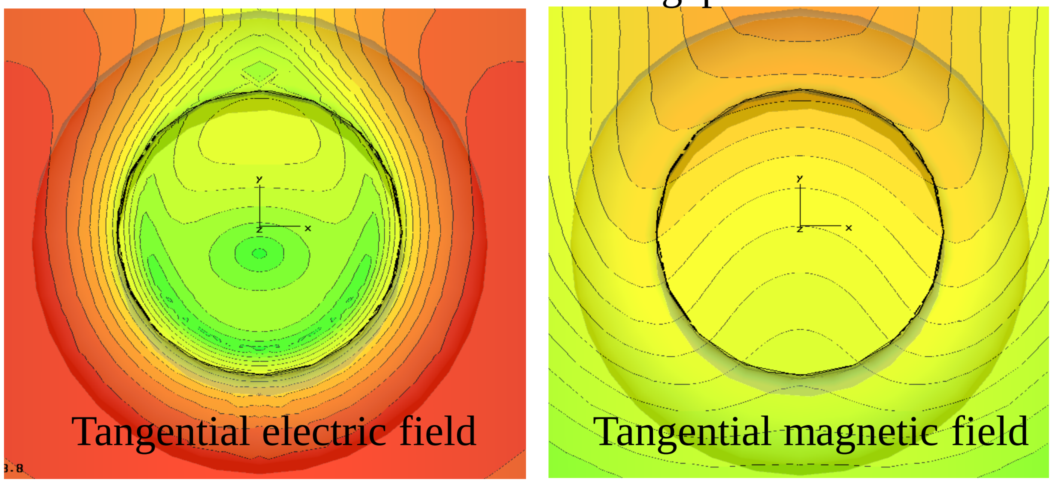
The RF design meets all requirements and it's good enough. The following additional optimization can make it even better:

1. The cavity radius is big as possible and we would like to keep it that big.
2. If beam dynamics and steering effect allow we can try to reduce the aperture radius.
3. If mechanical design allow we would like to return to conical stem.

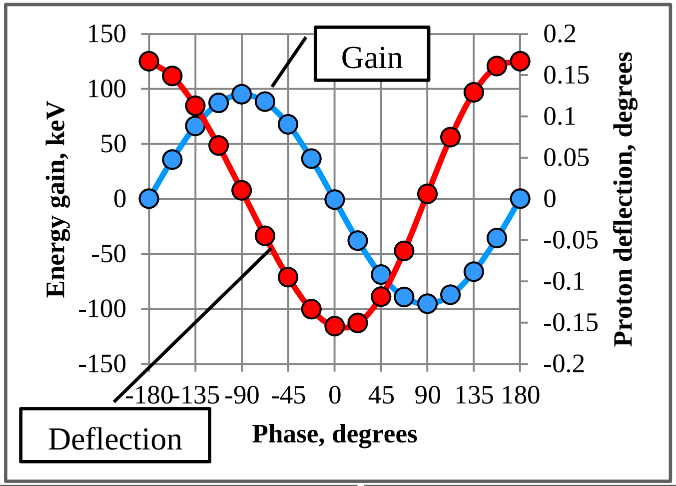


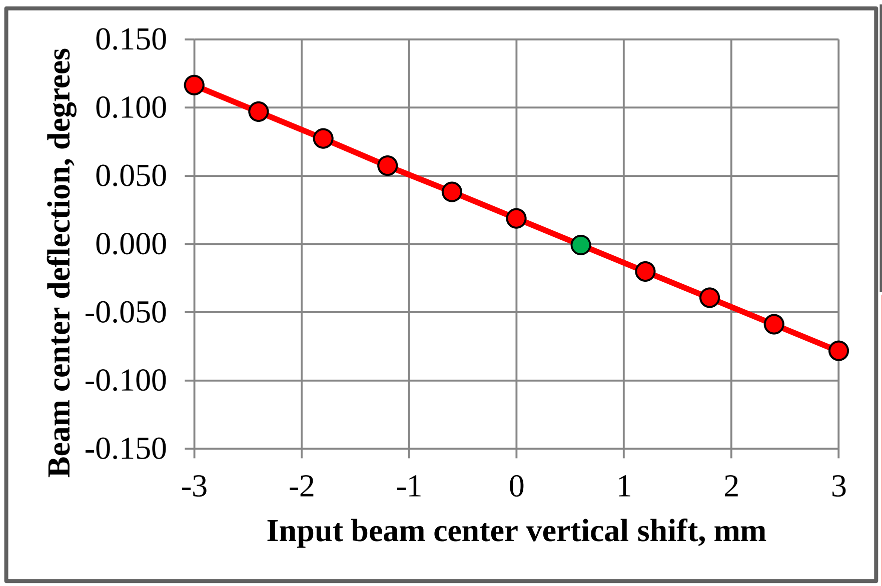
Beam steering

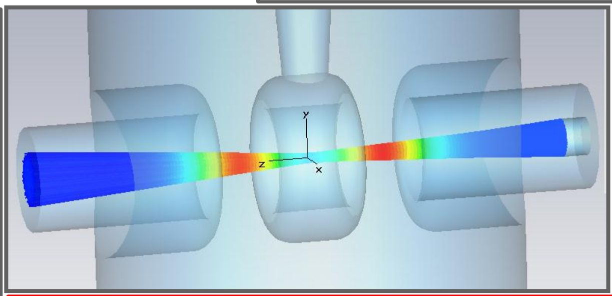
Field distributions in the gap center

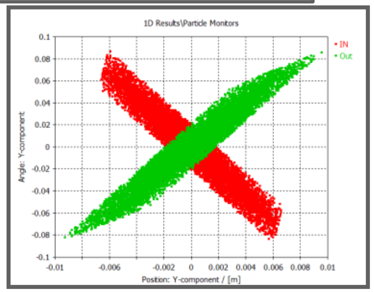


Single particle deflection, $x_0=y_0=0$









Because of low field, low proton energy and big aperture the steering effect is negligible. No emittance growth is observed. To compensate beam deflection completely the cavity should be shifted down by 0.6 mm.

Multipactoring in QWR re-buncher

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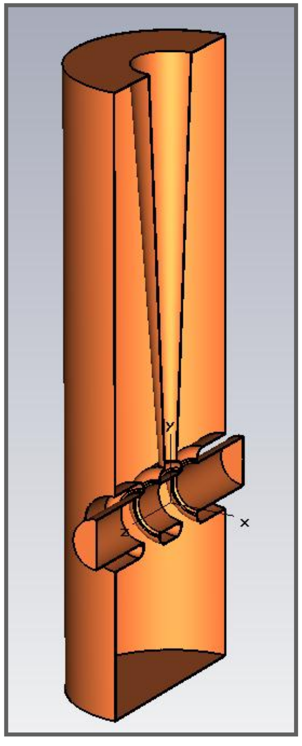
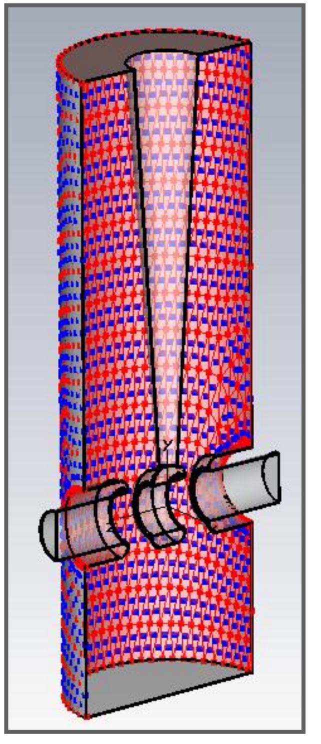
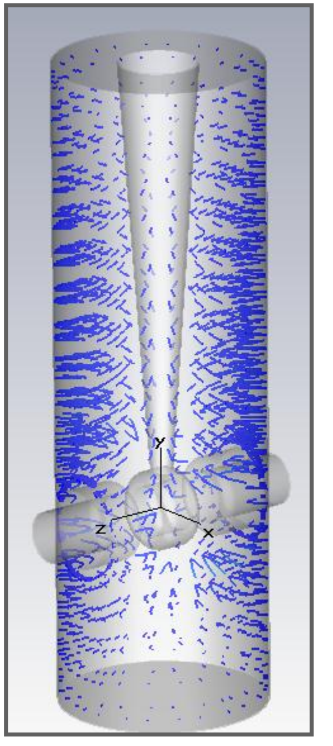


The CST Particle Studio was used to simulate multipactoring in QWR re-buncher. The key features of the CST PS are the advanced probabilistic secondary emission model and the multiparticle tracking.





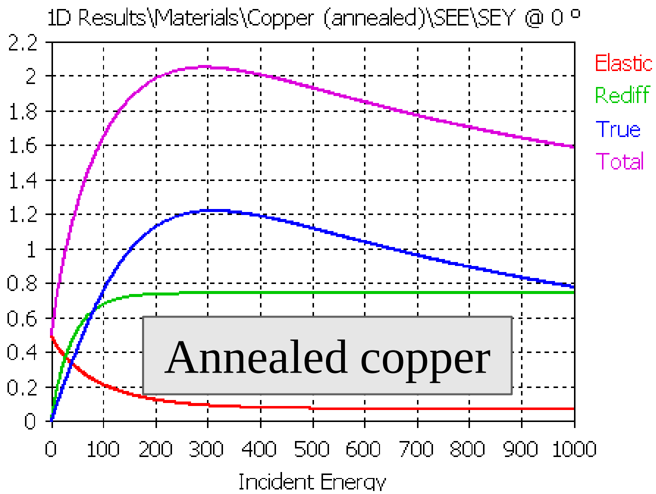
QWR re-buncher copper model

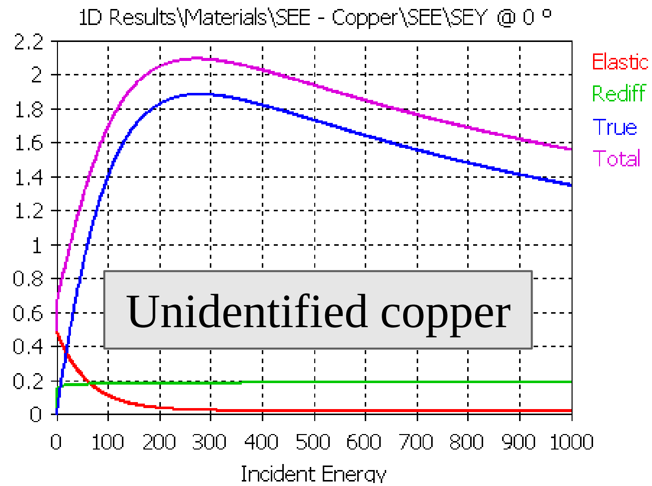
Electron source distribution

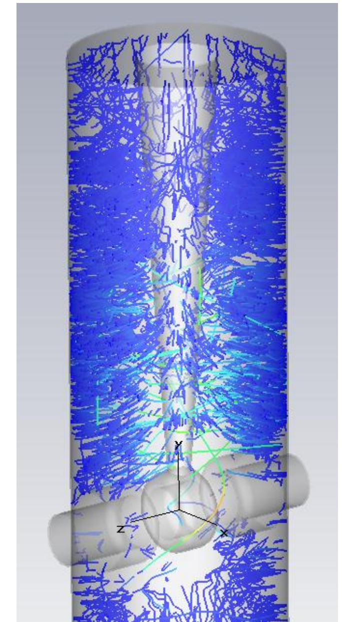
The launched electrons

Now the model has copper walls to assign emission properties. Initial electrons are uniformly distributed over cylinder inner surface. Electron initial energies are uniformly distributed over 0-4 eV interval. No initial angular distribution. Initial number of the electron was 1500-2500 in these simulations. All electrons are launched at the most favorable phase of RF field. The RF field amplitude is scanned to find multipactor zones.

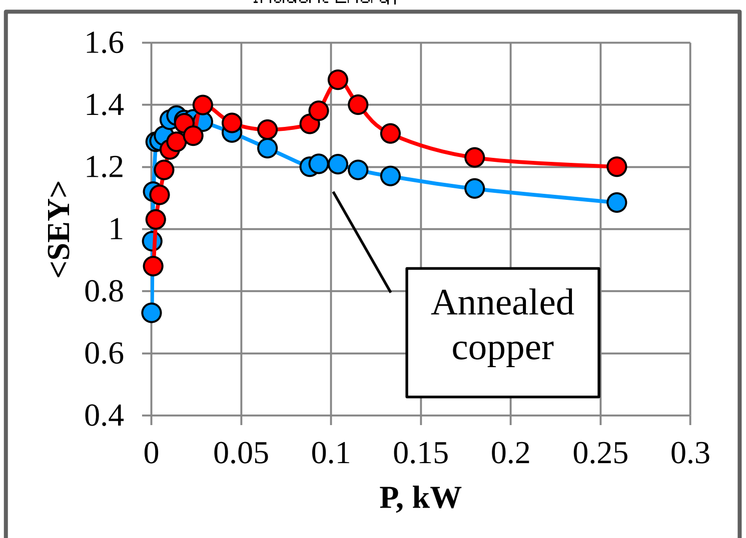
Multipactoring in QWR re-buncher

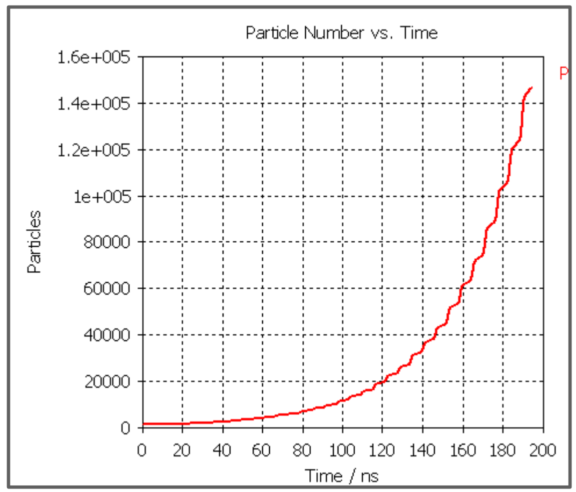


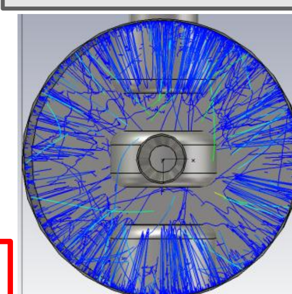




MP is typical for coaxials



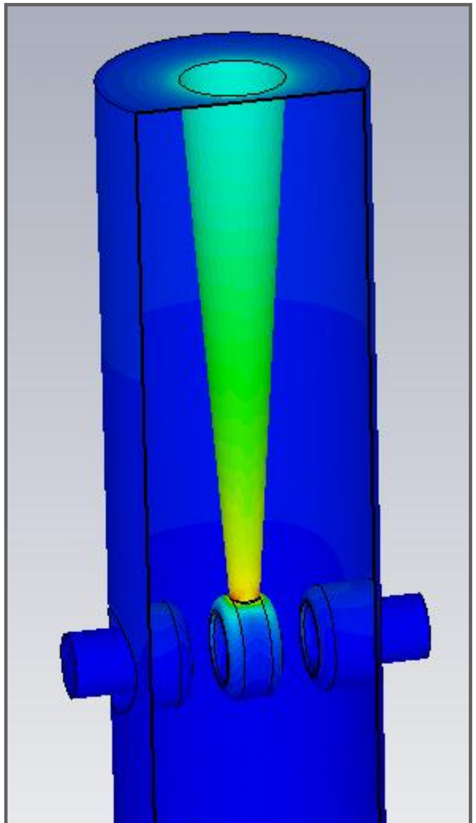




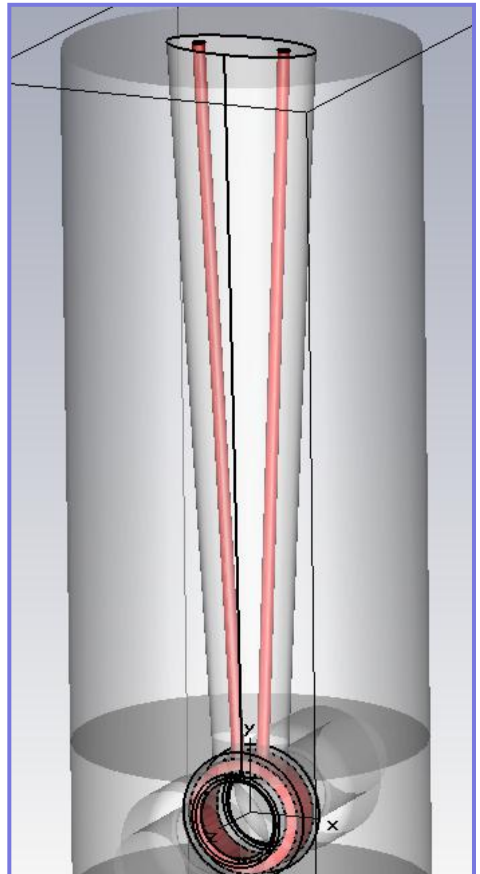
<SEY>=NumberOfSecondaries/NumberOfImpacts

Apparently we will have 1-2 MP barriers in 0-0.15 kW interval

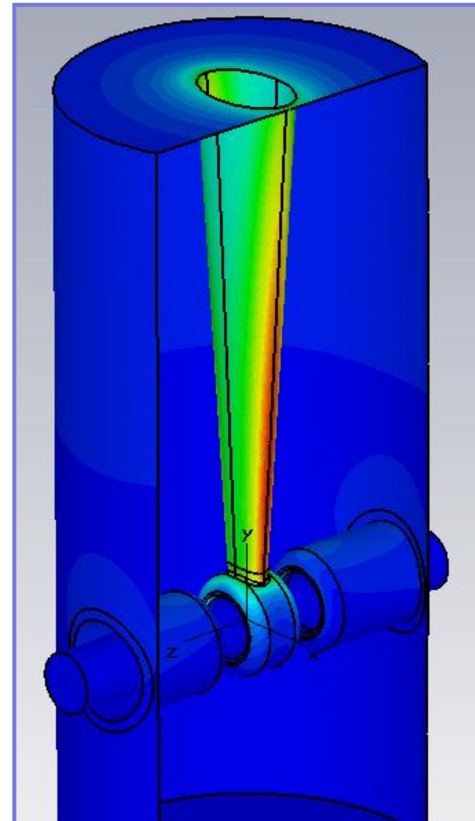
Power losses. Stem shape.



Loss density distribution.
Conical stem.



Initial cooling concept.



Loss density distribution.
Elliptical stem.

Most of the RF power is dissipated at the stem with high local power loss density. Therefore, the stem cooling mechanical design is a challenge.

Power coupler and tuners

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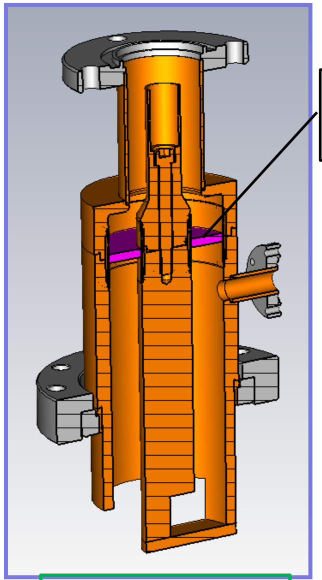
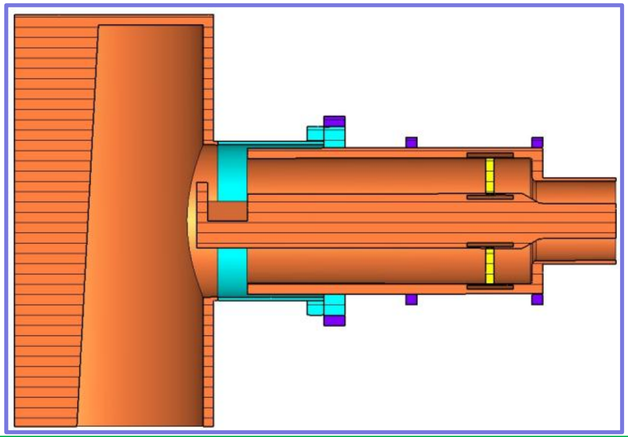
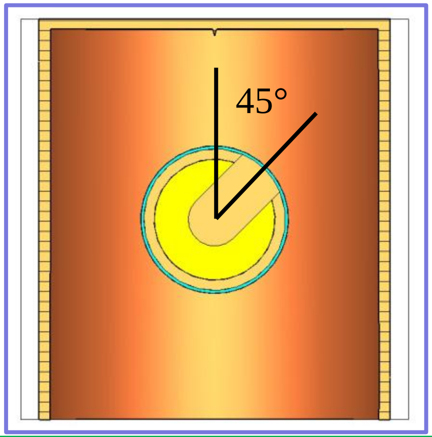


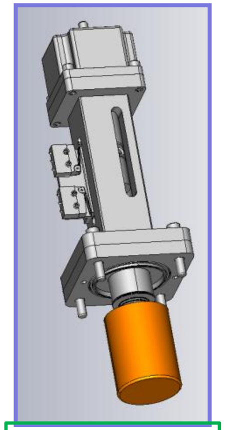
Ceramic window

HINS coupler



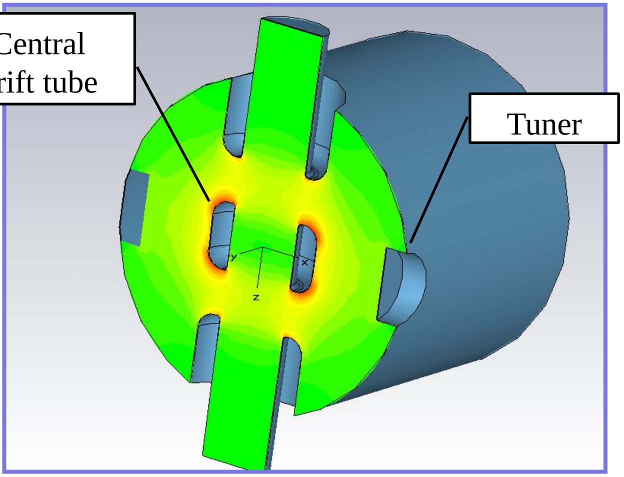


The coupler fits mechanically, position and orientation provide necessary coupling

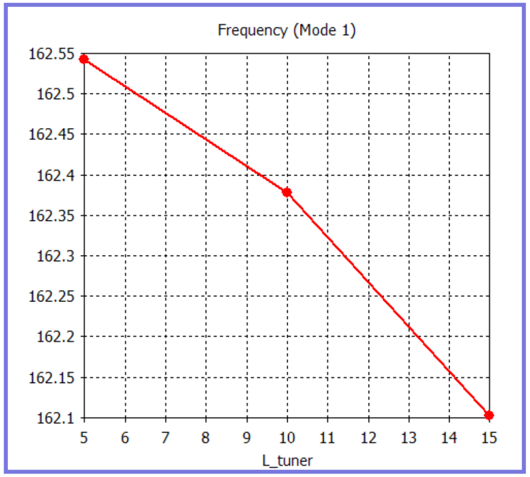


HINS tuner

Central drift tube

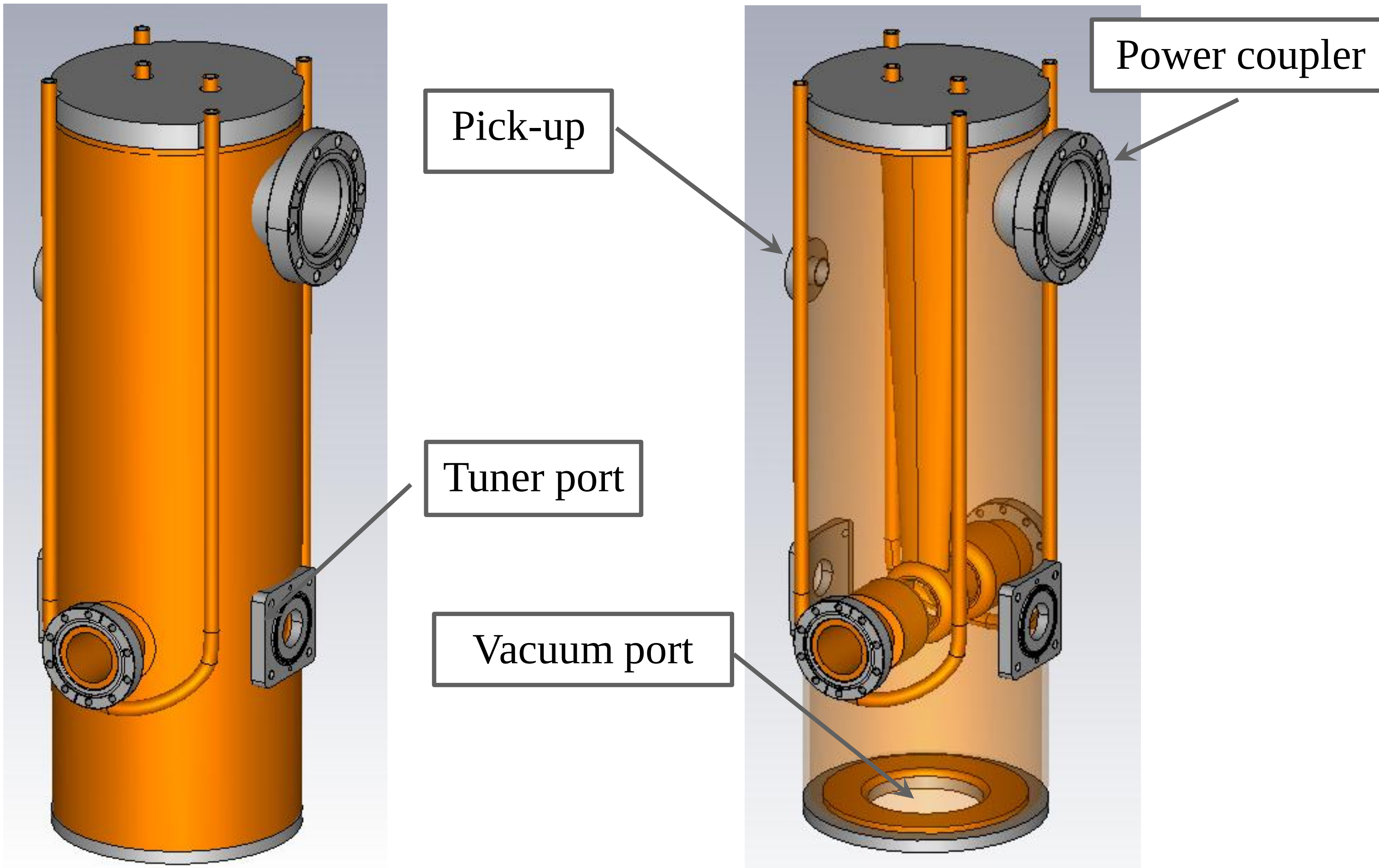


Tuner



Two tuners in electric field, ∅40 mm, combined sensitivity 44 kHz/mm, total tuning range 440 kHz

Current mechanical design



Thermo-stress analyses

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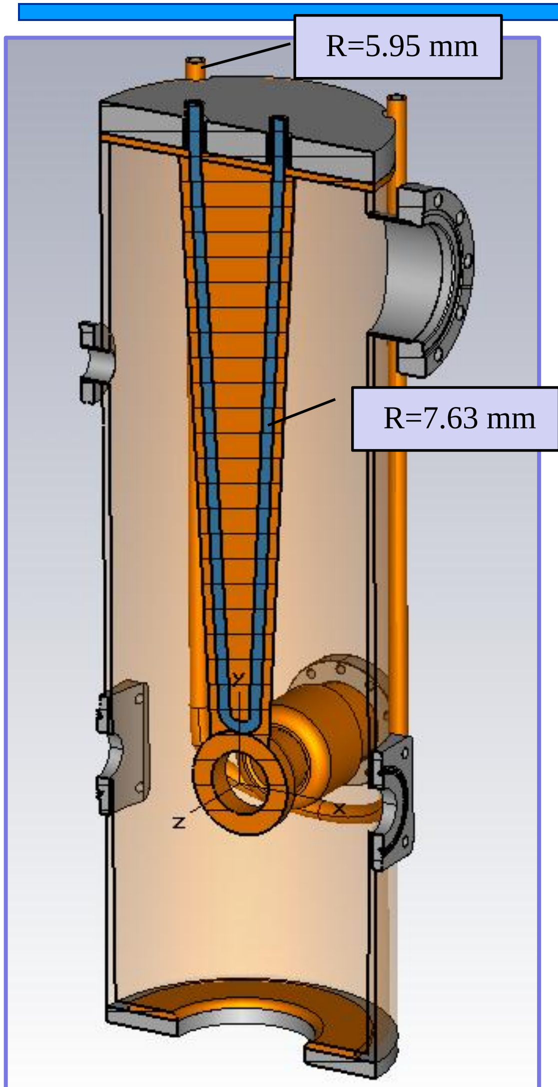
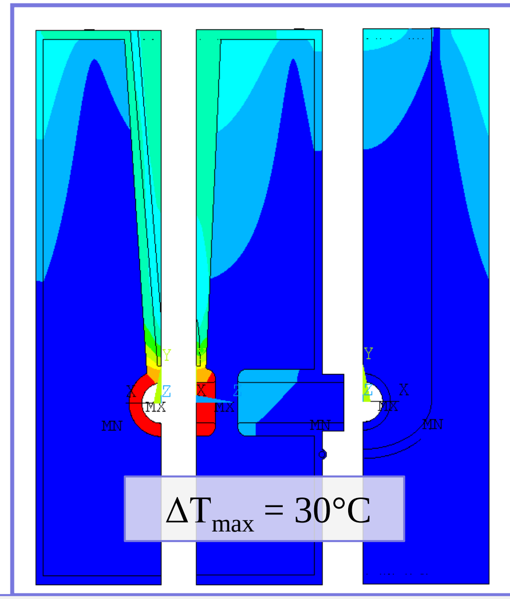
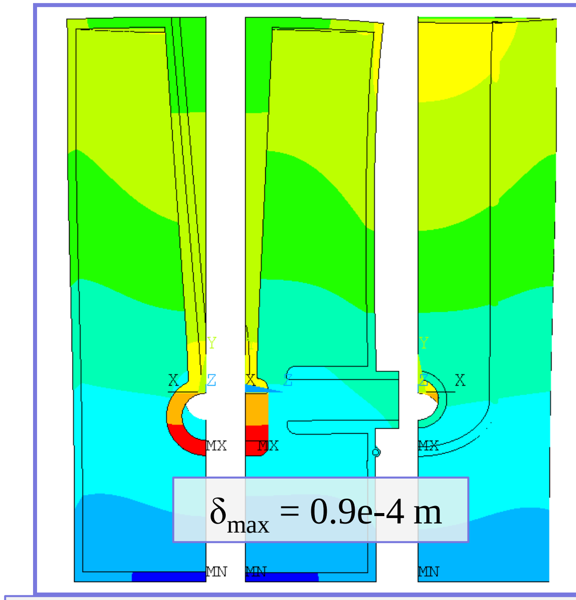


Principal cooling scheme



Temperature distribution. ΔT=30°C



Displacement (exaggerated view)

The thermo-stress analyses has been done for power losses of 3.2 kW (V_{eff} = 130 kV), so a safety margin of factor 3 is more than sufficient.

Frequency shift due to the thermal deformations is –49 KHz, that can be compensated by one tuner easily.

Thermo-analyses of the coupler

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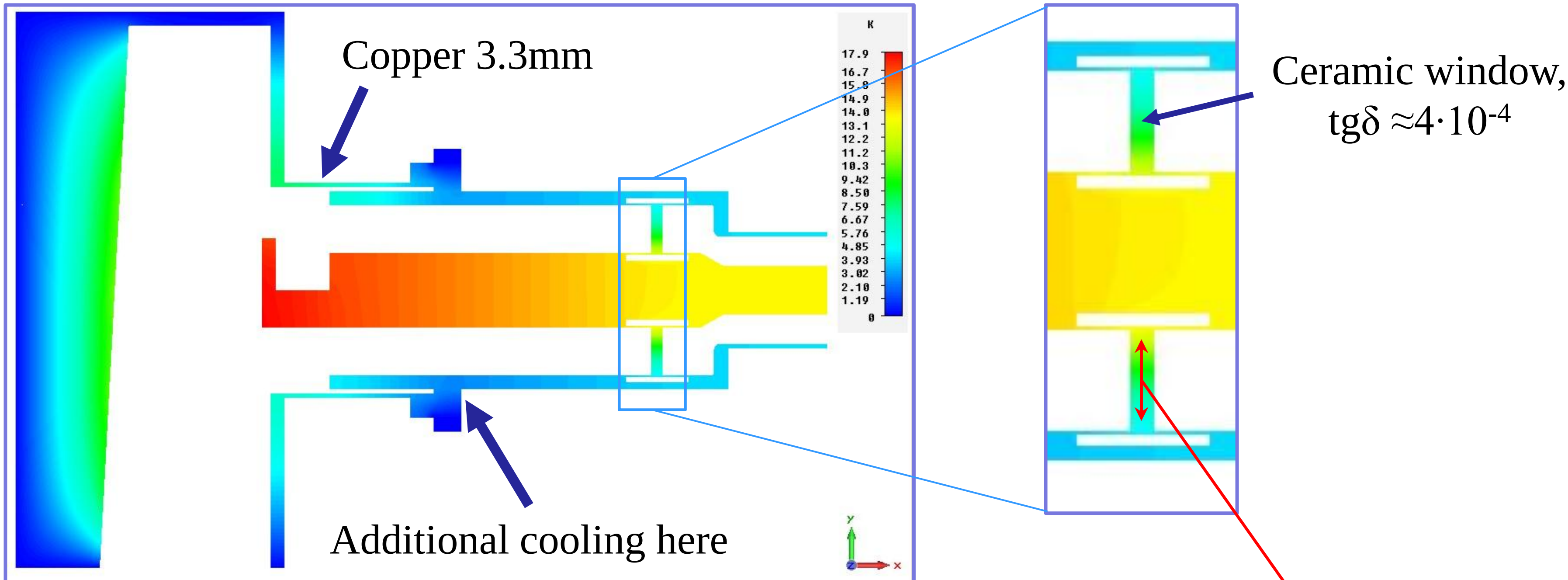
(Preliminary)



Several cooling schemes have been considered. This one looks most safe: gradient across ceramic and absolute temperature around ceramic is are small enough. (P = 4 kW).

Temperature gradient across ceramic window ≈0.46 °C/mm. It should work, if we compare with Toshiba 1 MW window, where gradient is ≈3 °C/mm.

Conclusion

- **The RF design of QWR re-buncher cavity is complete.**
- **Beam steering in the re-buncher is weak and can be easily compensated.**
- **Apparently there will be 1-2 multipactor barriers at low power level.**
- **The cooling of the cavity is sufficient.**
- **The mechanical design is ready in general.**
- **By preliminary evaluation the HINS power coupler and HINS tuners can be used.**